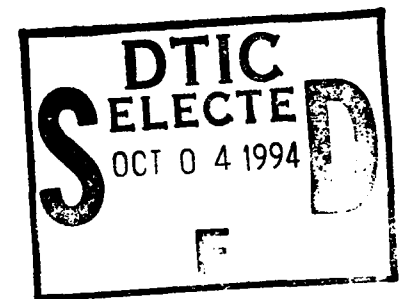AD-A285 182

Direct Comparison of Two Statistical Methods for Determination of Evoked-Potential Thresholds

By

Ted L. Langford
James H. Patterson, Jr.

Aircrew Protection Division

July 1994

94-31397

United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Animal use

In conducting the research described in this report, the investigators adhered to the Guide for Laboratory Animal Facilities and Care, as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences-National Research Council.
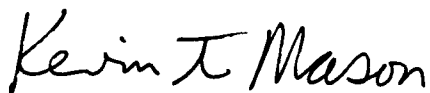
Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Reviewed:

KEVIN T. MASON
KEVIN T. MASON
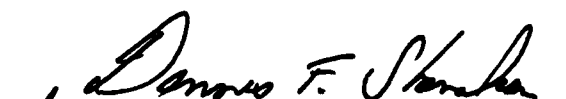LTC, MC, MFS
Director, Aircrew Protection
  Division

ROGER W. WILEY, O.D., Ph.D.
ROGER W. WILEY, O.D., Ph.D.
Chairman, Scientific
  Review Committee

Released for publication:

DAVID H. KARNEY
DAVID H. KARNEY
Colonel, MC, SFS
Commanding

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release, distribution unlimited	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL Report No. 94-38		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory	6b. OFFICE SYMBOL (If applicable) SGRD-UAS-AS	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research, Development, Acquisition and Logistics Command	
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 620577 Fort Rucker, AL 36362-0577		7b. ADDRESS (City, State, and ZIP Code) Fort Detrick Frederick, MD 21702-5012	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	

8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO. 61102A	PROJECT NO. 30161102BS15	TASK NO. JB	WORK UNIT ACCESSION NO. 282

11. TITLE (Include Security Classification)
Direct comparison of two statistical methods for determination of evoked-potential thresholds

12. PERSONAL AUTHOR(S)
Ted L. Langford and James H. Patterson, Jr.

13a. TYPE OF REPORT	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) 1994 July	15. PAGE COUNT 11

16. SUPPLEMENTARY NOTATION

17.	COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Evoked potentials, objective threshold determination,
05	01		chinchilla
06	04		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Several statistical procedures have been proposed as objective methods for determining
evoked-potential thresholds. Data have been presented to support each of the methods, but
there have not been direct comparisons using the same data. The goal of the present study
was to evaluate correlation and variance ratio statistics using common data. A secondary
goal was to evaluate the utility of a derived potential for determining thresholds.
Chronic, bipolar electrodes were stereotaxically implanted in the inferior colliculi of
six chinchillas. Evoked potentials were obtained at 0.25, 0.5, 1.0, 2.0, 4.0 and 8.0 kHz
using 12-ms tone bursts and 12-ms tone bursts superimposed on 120-ms pedestal tones which
were of the same frequency as the bursts, but lower in amplitude by 15 dB. Alternate
responses were averaged in blocks of 200 to 4000 depending on the size of the response.
Correlations were calculated for the pairs of averages. A response was deemed present if

DTIC QUALITY INSPECTED 3

(Continued on next page)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Chief, Science Support Center	22b. TELEPHONE (Include Area Code) 205-255-6907	22c. OFFICE SYMBOL SGRD-UAX-SI

DD Form 1473, JUN 86 — Previous editions are obsolete.

19. Abstract (continued).

the correlation coeffi   t reached the 0.05 level of significance in 4000 or fewer averages. Threshold   efined as the mean of the level at which the correlation was significant and a leve. 5 dB below that at which it was not. Variance ratios were calculated as described by Elberling and Don (1984) using the same data. Averaged tone burst and tone burst-plus pedestal data were differenced and the resulting waveforms subjected to the same statistical analyses described above. All analyses yielded thresholds which were essentially the same as those obtained using behavioral methods. When the difference between stimulus durations is taken into account, however, evoked-potential methods produced lower thresholds than behavioral methods.

Table of contents

List of figures

===

This page left blank intentionally.

===

Introduction

The chinchilla currently is the animal of choice for use as a model to establish the effects of various parameters of noise and blast exposure on auditory structure and function.

The behavioral methods in use for measuring hearing in the animal model are based on conditioning techniques (Miller, 1970; Blakeslee, et al., 1978). These methods provide valid and reliable measures of auditory thresholds when properly used, but do have limitations. First, the data may be affected by differing animal motivation from session to session and by the training procedures, particularly when multiple experimenters contribute to a single data pool. Second, the large investment of time and effort for both the training and measurement phases of an experiment limits the rate at which animals can be processed and makes the loss of an animal from a project extremely costly to the overall effort. A rapid, objective method for measuring hearing in the animal model would eliminate these limitations of the behavioral procedures.

A rapid method of threshold assessment, based on the detection of electrical responses of the auditory system to sound stimuli, now is being used in some laboratories (Bancroft, et al., 1991). A chronic electrode is implanted in the auditory system, usually in the inferior colliculus, and time-locked responses evoked by brief, rapidly repeated tone bursts are recorded, then averaged to improve the signal-to-noise ratio. Several stimulus presentations are made per second and a response can be detected visually in the averaged waveform after several hundred presentations. The thresholds obtained in this manner compare well with those derived from behavioral methods when signals of the same duration are used for both measures (Henderson, et al., 1983). Visual detection of the response is not objective, however, so it is subject to problems such as criterion differences between experimenters and criterion shifts across time for individual experimenters.

Several objective methods of detecting averaged electrical responses have been proposed for use in human evoked-response audiometry. Two of the methods outlined below have shown the most promise in terms of objectivity and reliability:

A statistical method based on correlation has been used by Arnold (1985), Salvi, et al. (1987), and Weber and Fletcher (1980). If time-locked responses to stimuli are present, the correlation between two averaged samples of those responses will be greater than that of the background activity. The background noise at the recording site is assumed to be random in the absence of a stimulus, so averaged samples of the noise taken at different times will not be correlated with one another. To

determine objectively the presence of responses, samples of activity time-locked to the stimulus are taken, averaged, and the correlation calculated between the two sets of averages. If the obtained correlation is greater significantly than that of the background, or zero, a response is present.

A second statistical method is based on evaluation of the ratio of the variance of the background noise to that of the response evoked by the stimulus (Elberling and Don, 1984; Don, Elberling and Waring, 1984). The variance for the background noise is estimated by sampling a single point of the response waveform across individual stimulus presentations. The variance of the response is calculated across points of the averaged recorded waveform. The ratio of the two variances follows the F-distribution and can be used to determine the presence of a response with any desired probability of error.

The third method, originally based on the visual detection of a derived response of the cochlear potential (Pantev and Pantev, 1982; Pantev et al., 1985), has been adapted by Berlin and his coworkers (Berlin et al., 1991; Hood et al., 1991) for use in evoked response work involving the central auditory system. A tone burst, some 20 dB above threshold, repeatedly is presented together with a continuous tone of the same frequency, but at a level near the expected threshold. The tone burst then is presented without the continuous tone. The responses to each of the stimulus configurations are averaged separately, and then the two sets of averaged data are differenced. The result is the response to the continuous tone. Lower thresholds have been obtained with this method than with more conventional methods. In addition, as the continuous tone has a narrower bandwidth than the tone burst, the derived response is more frequency-specific than can be obtained with conventional methods.

Each of these methods appears to have merit when compared with conventional, visual methods of threshold estimation, but they never have been directly compared with one another. The present experiment was designed to compare the two objective statistical methods with one another using both conventional tone-burst data and derived data from the differencing method of Berlin and his coworkers. The results will be compared with thresholds obtained using behavioral methods.

Methods

Six 1-to-2-year old male chinchillas bred and raised in the U.S. Army Aeromedical Research Laboratory (USAARL) colony were used as subjects. The animals were anesthetized by intramuscular injection of a combination of Ketamine (40 mg/kg) and Xylazine (2-5 mg/kg). The anesthetized animals were prepared for aseptic

surgery by plucking the fur from the top of the head, scrubbing
the plucked area, and swabbing it with Betadine. A lubricant was
applied to the eyes to prevent drying. The animal then was
placed in a stereotaxic instrument and draped. An incision was
made near the midline, the skin retracted, and the exposed skull
cleared of periosteum by scraping. The exposed portion of the
skull then was coated with a solution of silver nitrate followed
by a cyanoacrilate adhesive to provide a stable base for the
cement used in fixing the electrode in place. The skull was
marked according to previously determined stereotaxic coordinates
and a dental burr was used to make a 2 mm opening. After cutting
the dura, a concentric, bipolar electrode was lowered slowly into
the left inferior colliculus while electrical activity evoked by
a broadband click was monitored by an oscilloscope and an audio
system. At the proper depth, as determined by the best response
as well as by the stereotaxic coordinates, the electrode was
cemented in place. The incision was closed and a topical
antibiotic applied to the area.

Data collection was not initiated until a minimum of 2 weeks
was allowed for recovery from the procedure.

The animal was restrained for the electrophysiological
measurements in an apparatus designed for behavioral testing
(Blakeslee, et al., 1978). The apparatus fixed the animal's head
with respect to movement in the horizontal and coronal planes,
but did not prevent pinna movement or rotation of the head about
the interaural axis.

Equipment and procedures

Stimuli for the experiment were computer-generated and
controlled. An inverse-FFT routine was used to generate the
digital representations of the acoustic waveforms with
experimenter-specified frequencies, durations, phases, and
amplitude envelopes. The stimulus waveforms were calculated
prior to the experimental sessions and stored in memory. During
experimental sessions, they were output via 16-bit D-to-A
converters and filtered appropriately for the sampling rate.
After conversion and low-pass filtering, the stimuli were
amplified, then led to an electrically-shielded speaker located
inside a double-walled, sound-insulated booth. The speaker was
placed 1 meter in front of the animal. The sound field in the
position occupied by the animal's head was calibrated at each
frequency to be used prior to data collection. The calibration
results were used by the software to set the stimulus levels
desired for experimental conditions by means of a programmable
attenuator.

The stimuli were 12 ms tone bursts at 250, 500, 1000, 2000, 4000, and 8000 Hz. They had rise and decay durations of 6 ms. Previous evoked-potential work using these stimuli (Langford, Mozo and Patterson, 1989) showed them to have acceptable signal-to-noise ratios and bandwidths. The tone bursts were alternated with tone bursts temporally centered on a 120 ms tone of the same frequency, but at a level 15 dB below that of the burst. Since the time relation between the burst and the tone was fixed, the relative phases of the two differed at each frequency. At each frequency, the levels were varied in 5 dB steps over a 25 dB range encompassing the anticipated threshold. The number of repetitions was varied depending on the response magnitude obtained from each animal. In general, 200 to 400 repetitions for each level at each of four frequencies were run in each session. Each measurement session lasted approximately 45 minutes.

The experiment was designed so that the same data could be used to evaluate both of the statistical threshold determination methods under study. Data were collected beginning 3 ms after the onset of each tone burst for a period of 25.6 ms and for a like period of time beginning 51.2 ms after cessation of stimulation. This yielded background activity interleaved with responses to the tone bursts and with the tone bursts plus the long-duration tones. Each of the 25.6 ms data intervals contained 128 points. Data for each of the intervals were stored separately for off-line analysis.

The data for each stimulus condition were averaged later in blocks of 200 to 4000 repetitions. Each data epoch consisted of 128 points; however, adjacent points are not independent. The partial correlation between points has the effect of inflating the degrees of freedom used in the statistical tests. Since the lack of independence between points is a function of the frequency bandwidth used in the recording, autocorrelations were calculated for random noise samples generated with the same sampling rate and bandwidth used in data collection. The correlations approached zero when every fourth point was used in the calculations. Therefore, every fourth point was used in the computations of the correlations and variance ratios during data analysis.

Pairs of poststimulus waveforms, the results of averaging odd and even numbered responses to the stimulus presentations, were correlated (Pearson's r) with one another for each stimulus condition. The variance ratio for the entire set of data used in the correlation computations was calculated as $F = VAR(S)/VAR(N)$. VAR(S) is the variance of the averaged postsignal data taken during the temporal interval presumably containing the response. VAR(N) is the background noise variance calculated for a single point across all responses. This method of estimating the noise

variance has been shown to be an accurate measure of the variance of the true background noise (Elberling and Don, 1984). A response was deemed to be present if the 0.05 level of statistical significance was reached in 4000 or fewer trials. Threshold was defined as the mean of the lowest level at which a response was present and the level 5 dB below it at which no response was present.

Results and discussion

Tone-burst condition

With the exception of one frequency in one animal, there was perfect agreement between the thresholds obtained by the correlation and variance ratio methods for the traditional tone burst data. Since the two thresholds in that one case differed by only 5 dB, they were averaged and the audiograms produced by the two methods were considered the same. The tone burst thresholds are compared with a database of 118 behavioral thresholds obtained from the chinchilla by Patterson, et al. (1991) in Figure 1. The greatest differences occur at 0.5 and 8 kHz, where the separation between the two is only 3.8 dB.

The durations of the stimuli used in obtaining the two sets of thresholds were not the same, however. The evoked-potential data were obtained using stimuli with an effective duration of 4 ms (Dallos and Olsen, 1964), while the behavioral data are based on stimuli with durations exceeding the upper limit for temporal integration in the chinchilla. Henderson (1969), as well as others (Wall and Ferraro, 1981; Davis and Ferraro, 1983) have shown the chinchilla integrates the energy of an auditory stimulus in the same manner as human subjects, at least for durations up to 100 ms. This would place the 4 ms threshold stimuli used in the present study some 14 dB below those used for obtaining the behavioral thresholds. Thus, the sensitivity of either of the objective statistical methods, when applied to conventional evoked potential data, is greater considerably than that of behavioral methods.

A study by Arnold (1985), who used supra-threshold click-evoked data obtained from human subjects, also compared the correlation and variance ratio methods with a subjective, visual method for determining the presence of a response. At 10 dB above behavioral threshold, the lowest level used in that study, the correlation method was slightly more sensitive than the visual method and the variance ratio was the least sensitive. Her method for estimating the variance of the background activity was different from that used in the present study, however. In addition, two replications of 2000 averaged repetitions of stimulus-evoked activity interleaved with two runs of 2000
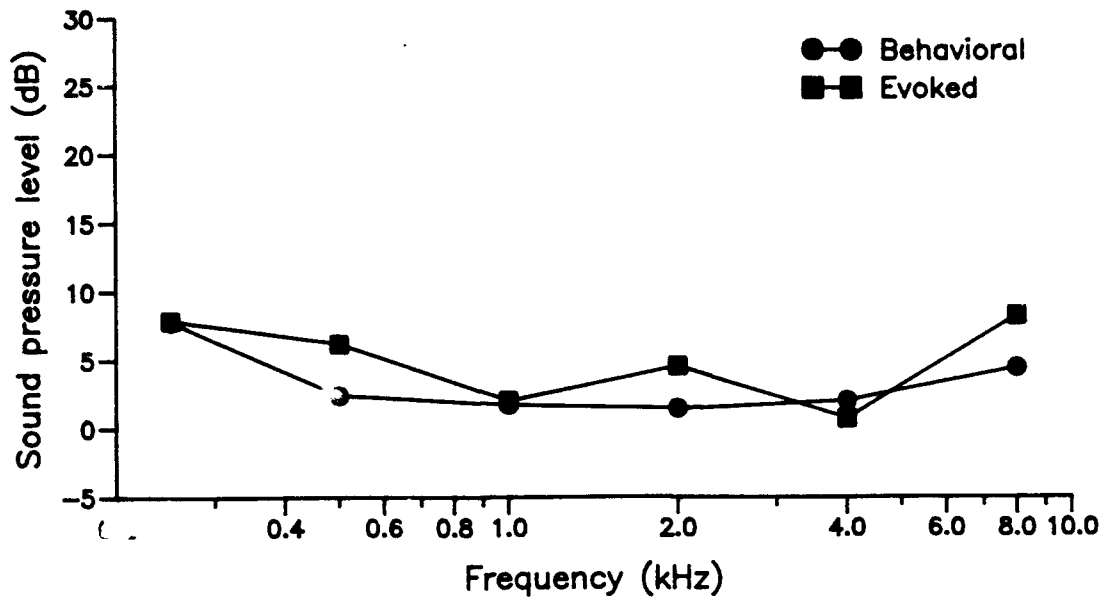
7

Figure 1. Behavioral thresholds compared with conventional tone-burst evoked thresholds of present study. Tone-burst evoked thresholds represent combined data from correlation and variance ratio methods.

averaged repetitions of background activity were used in those calculations, so that changes in the signal-to-noise ratio between samples could not be ruled out. Finally, no frequency-threshold values were obtained. Therefore, the results of that study cannot be compared directly with those of the present study.

Derived condition

The thresholds obtained from derived data using the two statistical methods did not show the high degree of correspondence found for the conventional tone-burst data. Differences of 5 dB between the correlation and variance ratio methods for at least one frequency in each of four animals were found. Because of these discrepancies, the thresholds for the two methods were treated separately. The two sets of thresholds are compared with the one obtained from the conventional tone burst method in Figure 2. Although others (Hood, et al., 1991) have reported lower thresholds for the chinchilla at the higher frequencies using the derived evoked-potential method, no such advantage was found in the present study. The thresholds based on the derived waveforms are parallel to and slightly higher than those obtained with the conventional method.
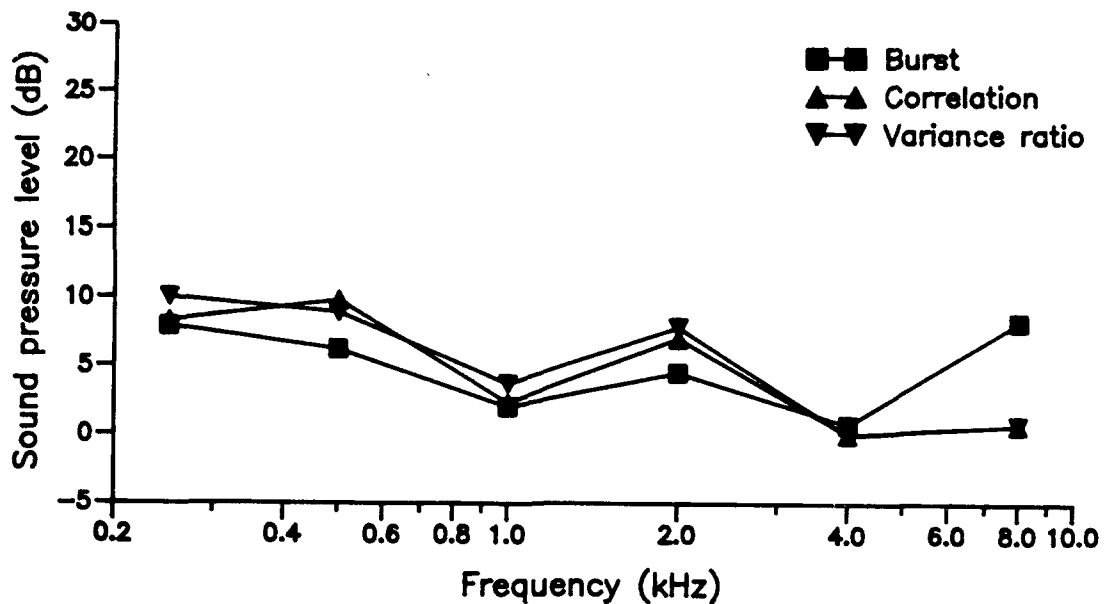
8

Figure 2.   Conventional tone-burst evoked thresholds compared
with derived thresholds. Tone-burst evoked thresh-
olds represent combined data from correlation and
variance ratio methods. Correlation and variance-
ratio derived thresholds are plotted separately.

Several procedural differences between the two studies may
explain the differences in the results. First, the thresholds
reported by Hood, et al. (1991) were based on subjective, visual
inspection of the data. Second, their evoked potentials were
recorded from surface electrodes and may represent activity from
different brain regions than those of the present study. Third,
their continuous tones and tone bursts were not phase-locked as
were those in the present study.

Conclusions

The objectively determined audiograms based on evoked-
potential methods are parallel to those based on behavioral
methods.

When the difference in stimulus duration between the evoked-
potential and behavioral methods is taken into account, the
evoked-potential method proves to be the more sensitive.

The derived-potential method, as implemented in the present
study, is less sensitive than the conventional evoked-potential
method.

9

References

Arnold, S. A. 1985. Objective versus visual detection of the auditory brain stem response. Ear and hearing. 6:144-150.

Bancroft, B. R., Boettcher, F. A., Salvi, R. J., and Wu, J. 1991. Effects of noise and salicylate on auditory evoked-response thresholds in the chinchilla. Hearing research. 54: 20-28.

Berlin, C. I., Hood, L. J., Barlow, E. K., Morehouse, C. R., and Smith, E. G. 1991. Derived guinea pig compound VIIIth nerve action potentials to continuous pure tones. Hearing research. 52:271-280.

Blakeslee, E. A., Hynson, K., Hamernik, R. P., and Henderson, D. 1978. Asymptotic threshold shift in chinchillas exposed to impulse noise. The journal of the acoustical society of America. 63:876-882.

Dallos, P. J., and Olsen, W. O. 1964. Integration of energy at threshold with gradual rise-fall tone pips. The journal of the acoustical society of America. 36:743-751.

Davis, R. I., and Ferraro, J. A. 1983. Temporal summation in normally and abnormally hearing chinchillas. The journal of auditory research. 23:281-292.

Don, M., Elberling, C., and Waring, M. 1984. Objective detection of averaged auditory brainstem responses. Scandinavian audiology. 13:219-228.

Elberling, C., and Don, M. 1984. Quality estimation of averaged auditory brainstem responses. Scandinavian audiology. 13:187-197.

Henderson, D. 1969. Temporal summation of acoustic signals by the chinchilla. The journal of the acoustical society of America. 46:474-475.

Hendersor). H., Hamernik, R. P., Salvi, R. J., and Ahroon, W. A. 1983. Comparison of auditory-evoked potentials and behavioral thresholds in the normal and noise-exposed chinchilla. Audiology. 22:172-180.

Henderson, D., Onishi, S., Eldridge, D., and Davis, H. 1969. A comparison of chinchilla auditory evoked response and behavioral response thresholds. Perception and psychophysics. 5:41-45.

Hood, L. J., Berlin, C. I., Heffner, R. S., Morehouse, C. R., Smith, E., and Barlow, E. K. 1991. Objective auditory threshold estimation using sine-wave derived responses. <u>Hearing research</u>. 55: 109-116.

Langford, T. L., Mozo, B. T., and Patterson, J. H., Jr. 1989. <u>Evaluation of two objective measures of effective auditory stimulus level</u>. Fort Rucker, AL: U. S. Army Aeromedical Research Laboratory, USAARL Report No. 89-18.

Miller, J. D. 1970. Audibility curve of the chinchilla. <u>The journal of the acoustical society of America</u>. 48:513-523.

Pantev, C., Lagidze, S., Pantev, M., and Kevanishvili, Z. 1985. Frequency-specific contributions to the auditory brain stem response derived by means of pure-tone masking. <u>Audiology</u>. 24:275-287.

Pantev, C. and Pantev, M. 1982. Derived brain stem responses by means of pure-tone masking. <u>Scandinavian audiology</u>. 11: 15-22.

Patterson, J. H., Jr., Carrier, M., Jr., Bordwell, K., Lomba Gautier, I. M., Hamernik, R. P., Ahroon, W. A., Turrentine, G., and Hargett, C. E., Jr. 1991. <u>The hazard of exposure to impulse noise as a function of frequency</u>. Fort Rucker, AL: U. S. Army Aeromedical Research Laboratory. USAARL Report No. 91-18. Volume 1.

Salvi, R. J., Ahroon, W., Saunders, S. S., and Arnold, S. A. 1987. Evoked potentials: Computer-automated threshold-tracking procedure using an objective detection criterion. <u>Ear and hearing</u>. 8:151-156.

Wall, L. G., and Ferraro, J. A. 1981. Temporal integration in the chinchilla. <u>The journal of auditory research</u>. 21:29-37.

Weber, B. A. and Fletcher, G. L. 1980. A computerized scoring procedure for auditory brainstem response audiometry. <u>Ear and hearing</u>. 1:233-236.

Initial distribution

Commander, U.S. Army Natick Research,
    Development and Engineering Center
ATTN: SATNC-MIL (Documents
    Librarian)
Natick, MA 01760-5040

Library
Naval Submarine Medical Research Lab
Box 900, Naval Sub Base
Groton, CT 06349-5900

Chairman
National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, DC 20594

Executive Director, U.S. Army Human
    Research and Engineering Directorate
ATTN: Technical Library
Aberdeen Proving Ground, MD 21005

Commander
10th Medical Laboratory
ATTN: Audiologist
APO New York 09180

Commander
Man-Machine Integration System
Code 602
Naval Air Development Center
Warminster, PA 18974

Naval Air Development Center
Technical Information Division
Technical Support Detachment
Warminster, PA 18974

Commander
Naval Air Development Center
ATTN: Code 602-B
Warminster, PA 18974

Commanding Officer, Naval Medical
    Research and Development Command
National Naval Medical Center
Bethesda, MD 20814-5044

Commanding Officer
Armstrong Laboratory
Wright-Patterson
Air Force Base, OH 45433-6573

Deputy Director, Defense Research
    and Engineering
ATTN: Military Assistant
    for Medical and Life Sciences
Washington, DC 20301-3080

Director
Army Audiology and Speech Center
Walter Reed Army Medical Center
Washington, DC 20307-5001

Commander, U.S. Army Research
    Institute of Environmental Medicine
Natick, MA 01760

Commander/Director
U.S. Army Combat Surveillance
    and Target Acquisition Lab
ATTN: SFAE-IEW-JS
Fort Monmouth, NJ 07703-5305

12

Director
Federal Aviation Administration
FAA Technical Center
Atlantic City, NJ 08405

Commander, U.S. Army Test
  and Evaluation Command
Directorate for Test and Evaluation
ATTN: AMSTE-TA-M (Human Factors
  Group)
Aberdeen Proving Ground,
  MD 21005-5055

Naval Air Systems Command
Technical Air Library 950D
Room 278, Jefferson Plaza II
Department of the Navy
Washington, DC 20361

Director
U.S. Army Ballistic
  Research Laboratory
ATTN: DRXBR-OD-ST Tech Reports
Aberdeen Proving Ground, MD 21005

Commander
U.S. Army Medical Research
  Institute of Chemical Defense
ATTN: SGRD-UV-AO
Aberdeen Proving Ground,
MD 21010-5425

Commander
USAMRDALC
ATTN: SGRD-RMS
Fort Detrick, Frederick, MD 21702-5012

Director
Walter Reed Army Institute of Research
Washington, DC 20307-5100

HQ DA (DASG-PSP-O)
5109 Leesburg Pike
Falls Church, VA 22041-3258

Harry Diamond Laboratories
ATTN: Technical Information Branch
2800 Powder Mill Road
Adelphi, MD 20783-1197

U.S. Army Materiel Systems
  Analysis Agency
ATTN: AMXSY-PA (Reports Pr   ng)
Aberdeen Proving Ground
MD 21005-5071

U.S. Army Ordnance Center
  and School Library
Simpson Hall, Building 3071
Aberdeen Proving Ground, MD 21005

U.S. Army Environmental
  Hygiene Agency
ATTN: HSHB-MO-A
Aberdeen Proving Ground, MD 21010

Technical Library Chemical Research
  and Development Center
Aberdeen Proving Ground, MD
21010-5423

Commander
U.S. Army Medical Research
  Institute of Infectious Disease
ATTN: SGRD-UIZ-C
Fort Detrick, Frederick, MD 21702

Director, Biological
  Sciences Division
Office of Naval Research
600 North Quincy Street
Arlington, VA 22217

Commandant
U.S. Army Aviation
   Logistics School ATTN: ATSQ-TDN
Fort Eustis, VA 23604

Headquarters (ATMD)
U.S. Army Training
   and Doctrine Command
ATTN: ATBO-M
Fort Monroe, VA 23651

IAF Liaison Officer for Safety
USAF Safety Agency/SEFF
9750 Avenue G, SE
Kirtland Air Force Base
NM 87117-5671

Naval Aerospace Medical
   Institute Library
Building 1953, Code 03L
Pensacola, FL 32508-5600

Command Surgeon
HQ USCENTCOM (CCSG)
U.S. Central Command
MacDill Air Force Base, FL 33608

Director
Directorate of Combat Developments
ATTN: ATZQ-CD
Building 515
Fort Rucker, AL 36362

U.S. Air Force Institute
   of Technology (AFIT/LDEE)
Building 640, Area B
Wright-Patterson
Air Force Base, OH 45433

Henry L. Taylor
Director, Institute of Aviation
University of Illinois-Willard Airport
Savoy, IL 61874

Chief, National Guard Bureau
ATTN: NGB-ARS
Arlington Hall Station
111 South George Mason Drive
Arlington, VA 22204-1382

Commander
U.S. Army Aviation and Troop Command
ATTN: AMSAT-R-ES
4300 Goodfellow Bouvelard
St. Louis, MO 63120-1798

U.S. Army Aviation and Troop Command
   Library and Information Center Branch
ATTN: AMSAV-DIL
4300 Goodfellow Boulevard
St. Louis, MO 63120

Federal Aviation Administration
Civil Aeromedical Institute
Library AAM-400A
P.O. Box 25082
Oklahoma City, OK 73125

Commander
U.S. Army Medical Department
   and School
ATTN: Library
Fort Sam Houston, TX 78234

Commander
U.S. Army Institute of Surgical Research
ATTN: SGRD-USM
Fort Sam Houston, TX 78234-6200

AAMRL/HEX
Wright-Patterson
Air Force Base, OH 45433

Air Unoiversity Library
(AUL/LSE)
Maxwell Air Force Base, AL 36112

14

Product Manager
Aviation Life Support Equipment
ATTN: SFAE-AV-LSE
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

Commander and Director
USAE Waterways Experiment Station
ATTN: CEWES-IM-MI-R,
  CD Department
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Commanding Officer
Naval Biodynamics Laboratory
P.O. Box 24907
New Orleans, LA 70189-0407

Assistant Commandant
U.S. Army Field Artillery School
ATTN: Morris Swott Technical Library
Fort Sill, OK 73503-0312

Mr. Peter Seib
Human Engineering Crew Station
Box 266
Westland Helicopters Limited
Yeovil, Somerset BA20 2YB UK

U.S. Army Dugway Proving Ground
Technical Library, Building 5330
Dugway, UT 84022

U.S. Army Yuma Proving Ground
Technical Library
Yuma, AZ 85364

AFFTC Technical Library
6510 TW/TSTL
Edwards Air Force Base,
CA 93523-5000

Commander
Code 3431
Naval Weapons Center
China Lake, CA 93555

Aeromechanics Laboratory
U.S. Army Research and Technical Labs
Ames Research Center, M/S 215-1
Moffett Field, CA 94035

Sixth U.S. Army
ATTN: SMA
Presidio of San Francisco, CA 94129

Commander
U.S. Army Aeromedical Center
Fort Rucker, AL 36362

Strughold Aeromedical Library
Document Service Section
2511 Kennedy Circle
Brooks Air Force Base, TX 78235-5122

Dr. Diane Damos
Department of Human Factors
ISSM, USC
Los Angeles, CA 90089-0021

U.S. Army White Sands
  Missile Range
ATTN: STEWS-IM-ST
White Sands Missile Range, NM 88002

U.S. Army Aviation Engineering
  Flight Activity
ATTN: SAVTE-M (Tech Lib) Stop 217
Edwards Air Force Base, CA 93523-5000

Ms. Sandra G. Hart
Ames Research Center
MS 262-3
Moffett Field, CA 94035

Commander
USAMRDALC
ATTN: SGRD-UMZ
Fort Detrick, Frederick, MD 21702-5009

Commander
U.S. Army Health Services Command
ATTN: HSOP-SO
Fort Sam Houston, TX 78234-6000

U. S. Army Research Institute
Aviation R&D Activity
ATTN: PERI-IR
Fort Rucker, AL 36362

Commander
U.S. Army Safety Center
Fort Rucker, AL 36362

U.S. Army Aircraft Development
  Test Activity
ATTN: STEBG-MP-P
Cairns Army Air Field
Fort Rucker, AL 36362

Commander
USAMRDALC
ATTN: SGRD-PLC (COL R. Gifford)
Fort Detrick, Frederick, MD 21702

TRADOC Aviation LO
Unit 21551, Box A-209-A
APO AE 09777

Netherlands Army Liaison Office
Building 602
Fort Rucker, AL 36362

British Army Liaison Office
Building 602
Fort Rucker, AL 36362

Italian Army Liaison Office
Building 602
Fort Rucker, AL 36362

Directorate of Training Development
Building 502
Fort Rucker, AL 36362

Chief
USAHEL/USAAVNC Field Office
P. O. Box 716
Fort Rucker, AL 36362-5349

Commander, U.S. Army Aviation Center
  and Fort Rucker
ATTN: ATZQ-CG
Fort Rucker, AL 36362

Chief
Test & Evaluation Coordinating Board
Cairns Army Air Field
Fort Rucker, AL 36362

Canadian Army Liaison Office
Building 602
Fort Rucker, AL 36362

German Army Liaison Office
Building 602
Fort Rucker, AL 36362

French Army Liaison Office
USAAVNC (Building 602)
Fort Rucker, AL 36362-5021

Australian Army Liaison Office
Building 602
Fort Rucker, AL 36362

Dr. Garrison Rapmund
6 Burning Tree Court
Bethesda, MD 20817

16

Commandant, Royal Air Force
Institute of Aviation Medicine
Farnborough, Hampshire GU14 6SZ UK

Defense Technical Information
Cameron Station, Building 5
Alexandra, VA 22304-6145

Commander, U.S. Army Foreign Science
and Technology Center
AIFRTA (Davis)
220 7th Street, NE
Charlottesville, VA 22901-5396

Commander
Applied Technology Laboratory
USARTL-ATCOM
ATTN: Library, Building 401
Fort Eustis, VA 23604

Commander, U.S. Air Force
Development Test Center
101 West D Avenue, Suite 117
Eglin Air Force Base, FL 32542-5495

Aviation Medicine Clinic
TMC #22, SAAF
Fort Bragg, NC 28305

Dr. H. Dix Christensen
Bio-Medical Science Building, Room 753
Post Office Box 26901
Oklahoma City, OK 73190

Commander, U.S. Army Missile
Command
Redstone Scientific Information Center
ATTN: AMSMI-RD-CS-R
/ILL Documents
Redstone Arsenal, AL 35898

Director
Army Personnel Research Establishment
Farnborough, Hants GU14 6SZ UK

U.S. Army Research and Technology
Laboratories (AVSCOM)
Propulsion Laboratory MS 302-2
NASA Lewis Research Center
Cleveland, OH 44135

Commander
USAMRDALC
ATTN: SGRD-ZC (COL John F. Glenn)
Fort Detrick, Frederick, MD 21702-5012

Dr. Eugene S. Channing
166 Baughman's Lane
Frederick, MD 21702-4083

U.S. Army Medical Department
and School
USAMRDALC Liaison
ATTN: HSMC-FR
Fort Sam Houston, TX 78234

Dr. A. Kornfield
895 Head Street
San Francisco, CA 94132-2813

NVESD
AMSEL-RD-NV-ASID-PST
(Attn: Trang Bui)
10221 Burbeck Road
Fort Belvior, VA 22060-5806

CA Av Med
HQ DAAC
Middle Wallop
Stockbridge, Hants S020 8DY UK

Dr. Christine Schlichting
Behavioral Sciences Department
Box 900, NAVUBASE NLON
Groton, CT 06349-5900

Commander, HQ AAC/SGPA
Aerospace Medicine Branch
162 Dodd Boulevard, Suite 100
Langley Air Force Base,
VA 23665-1995

Commander
Aviation Applied Technology Directorate
ATTN: AMSAT-R-TV
Fort Eustis, VA 23604-5577

COL Yehezkel G. Caine, MD
Surgeon General, Israel Air Force
Aeromedical Center Library
P. O. Box 02166 I.D.F.
Israel

Director
Aviation Research, Development
   and Engineering Center
ATTN: AMSAT-R-Z
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

Commander
USAMRDALC
ATTN: SGRD-ZB (COL C. Fred Tyner)
Fort Detrick, Frederick, MD 21702-5012

Commandant
U.S. Army Command and General Staff
   College
ATTN: ATZL-SWS-L
Fort Levenworth, KS 66027-6900